# The complex X-ray diagnostics of the ordinary chondrites Markovka, Polujamki and Jiddat Al Harasis 055

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*Introduction.* The structure and composition of ordinary chondrites contain information about presolar, nebular and asteroidal stage of evolution. The various oxidation states of iron can be used to describe physicochemical processes of meteorites history, such as aqueous alteration and thermal metamorphism. Iron in fresh meteorites can exist as $Fe^0$ in Fe-Ni metal, $Fe^{2+}$ in silicates and sulfides and $Fe^{3+}$ in phyllosilicates and magnetite. During fluid/rock interaction, iron as $Fe^0$ and $Fe^{2+}$ are transformed into $Fe^{3+}$-rich phases. In the present study we use micro X-ray fluorescence (XRF) analysis, X-ray diffraction (XRD) and X-ray absorption near-edge structure (XANES) spectroscopy to characterize the element and phase composition and the oxidation state of iron in the ordinary chondrites Markovka (H4 petrologic type meteorite), Polujamki (H4 type) and Jiddat Al Harasis 055 (L4-5 type).

*Methods.* XRF has been done using a 2D micro X-ray fluorescence spectrometer M4 Tornado (Bruker). XRD has been performed using a X-ray difractometer D2 Phaser (Bruker). Fe *K*-edge XANES spectra of the meteorites have been registered using a laboratory X-ray absorption spectrometer R-XAS Looper (Rigaku). A Ge (311) crystal monochromator was used providing energy resolution 1.4 eV at 7100 eV photon energy. XANES spectra were measured both in fluorescence mode for samples polished by diamond tip and in transmission mode for pressed tablets containing mixture of the milled meteorite under study and cellulose.

*Results and discussion.* XRF analysis has shown that the concentration of iron in the bulk of the meteorites varied from 35 to 83%. Other abundant elements were Si (5-30%), Mg (3-20%), Ni (0.5-4%), Ca (1-14%) and S (0.5-17%). XRF elemental mapping for the bulk of the meteorites were done. XRD, as well as Mössbauer spectroscopy of Fe-containing phases, showed that the meteorites consist mainly from olivine and goethite with trace amount of pyroxene and hematite. The Fe oxidation state of the chondrites has been estimated by comparing the absorption edges of the Fe *K*-XANES spectra of the studied meteorites (with an unknown Fe oxidation state) and reference samples (with well known Fe oxidation state) - $Fe^0$, $Fe^{2+}O$, $\alpha$-$Fe^{3+}{}_2O_3$, $\gamma$-$Fe^{3+}{}_2O_3$, $Fe^{2+,3+}{}_3O_4$. XANES spectra analysis has shown that the Fe in the studied meteorites is mainly in +2 oxidation state with a small fraction of +3 which agreed with Mössbauer data.

*Conclusions.* Element and phase compositions of the chondrites Markovka, Polujamki and Jiddat Al Harasis 055 have been determined by XRF and XRD. The Fe oxidation state of the chondrites has been estimated by the Fe *K*-XANES analysis. It has been shown that XANES spectroscopy is an efficient method for describing the Fe oxidation state in the ordinary chondrites. The obtained data may be useful for future analysis of formation processes of the meteorites.

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